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ABSTRACT

A study involving 103 male and 117 female students entering a major urban university assessed the interaction between test anxiety and skill deficits. The effects of prior achievement and test anxiety on performance on two competency exams were also examined. Instruments consisted of minimum competency tests for reading comprehension and mathematics and a self-report measure of test anxiety (the Test Anxiety Inventory). Two competing explanations of the role of test anxiety--cognitive interference and skill deficits--were examined using a structural equation model. The interference hypothesis assumes that anxiety interferes with cognitive processing during testing, while the deficit hypothesis suggests that poor performance of test-anxious examinees is attributable to skill deficits and/or an interaction between test anxiety and skill deficits. Prior achievement, test anxiety, and their interaction were represented in a structural equation model as causal influences on test performance. Results suggest that test anxiety (i.e., worrying) and skill (as evidenced in prior academic achievement) contribute to performance and that these effects differ across tests. The interaction term did not add significantly to the explanation of performance. Findings are discussed in terms of their implications for test anxiety theory and competency testing. Three data tables and two figures conclude the document. (Author/TJH)

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Test Anxiety and Skill Deficits: A Test of Two Competing Hypotheses

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Abstract

The issue of whether test anxiety is a useful construct for understanding performance on competency tests is addressed. Two competing explanations of the role of test anxiety, cognitive interference and skill deficits, are examined empirically using a structural equation model. The interference hypothesis assumes that anxiety interferes with cognitive processing during testing, while the competing deficit hypothesis suggests that the poor performance of test anxious examinees is attributable to skill deficits and/or an interaction between test anxiety and skill deficits. We examined the performance of 220 participants (103 males and 117 females) on two tests of minimum competency, reading comprehension and mathematics. Prior achievement, test anxiety, and their interaction were represented in a structural equation model as causal influences on test performance. Results suggest that test anxiety (i.e., worrying) and skill (i.e., prior academic achievement) contribute to performance and that these effects differ across tests. The interaction term did not add significantly to the explanation of performance. Findings are discussed in terms of their implications for test anxiety theory and competency testing.

Introduction

Research examining the effects of test anxiety in situations involving evaluative stress, such as achievement or competency testing, reveals that highly test-anxious examinees do not perform as well as their less anxious counterparts (Benjamin, McKeachie, Lin, & Hollinger, 1981; McKeachie, 1984; McKeachie, Pollie, & Spiesman, 1955; Sarason, 1980; Sieber, O'Neil, & Tobias, 1977). Current test anxiety theory (Sarason, 1980) is based on a cognitive interference model which assumes that anxiety during testing interferes with the ability to retrieve and use previously learned information. The interference attributed to test anxiety has been explained by variations in the way students deploy their attention (Sarason, 1972, 1984; Wine, 1971, 1980). Support for the interference model has come from the work of Morris, Davis, & Hutchings (1981) and Deffenbacher (1980) which demonstrated that the cognitive component of test anxiety, i.e., worry, correlates strongly with academic performance. Highly anxious students are believed to divide their attention between task demands and concerns of negative self-preoccupations (worrying), while low test-anxious students are presumed to allocate a greater proportion of their attention to the task demands (Sarason & Sarason, 1987).

As others have noted recently (Paulman & Kennelly, 1984; Tobias, 1985), the interference model of test anxiety has been challenged by an alternative deficit hypothesis, which assumes the performance decrements observed in test anxious students are attributable directly to skill deficits (Culler & Holahan, 1980; Kirkland & Hollandsworth 1979, 1980). The skills deficit hypothesis is based on findings relating both performance and anxiety to study skills measures. Disederato and Koskinen (1969), Mitchell and Ng (1972), and Wittmaier (1972) found that anxious students had less effective study skills than those lower in anxiety. Kirkland and Hollandsworth (1979) imply that defective skills may supplant test anxiety as the operative construct. They state, for example, that..."one cannot help but raise the question of whether anxiety interferes with effective test-taking behavior [sic performance] or whether the lack of effective skills results in test anxiety" (p. 435).

For the most part, current test anxiety research leaves unresolved the issue of explaining the relative contribution of test anxiety and skill level on competency testing. Are both constructs necessary to adequately explain performance? Does skill level interact with anxious worrying to cause poor performance? These questions can be addressed by defining them as competing hypotheses and testing how well they account for the patterns of covariation in a set of observations.

If, for example, knowledge of the student's level of test anxiety contributes to an understanding of test performance, independent of the student's skill level, then the interference hypothesis would be supported. On the other hand, if skill level or the interaction of skill level and anxiety adequately explains performance on competency tests, the deficit hypothesis would prevail. Using the general framework of linear structural equation modeling (Joreskog & Sorbom,1979; Loehlin, 1987; Saris & Stronkhorst, 1984), these competing models can be tested empirically. This approach, sometimes referred to as an analysis of covariance structures (Kerlinger, 1986), uses a combination of factor analysis and multiple regression analysis to assess the effects of latent and observed variables on each other. In this paper we contrast the interference and deficit models by examining the effects of two explanatory variables, test anxiety and skill level, on performance on two standardized tests, a measure of reading comprehension and test of mathematics achievement.

Theoretical Model

To test the competing models, we developed the structural model that appears in Figure 1. This model contains four constructs, represented by two observed variables and two latent variables. The observed variables represent prior academic achievement (a proxy for skill level) and worry, the cognitive component of test anxiety (Sarason & Sarason, 1987). The latent, or unobserved variables include reading comprehension and mathematics achievement. These four variables, along with a term representing the interaction of worry and prior achievement, comprise the theoretical structural model of test anxiety and academic achievement.

Once the theoretical variables and the observed measures are made explicit, expressing the relationships in equation form is straightforward. These relations are expressed in two stages: (1) relations among measures to theoretical variables, i.e., the measurement model and; (2) the relations among theoretical variables, i.e., a structural model. The LISREL program (Joreskog & Sorbom, 1984) was used to generate estimates for all unknown parameters in the model. Linear structural equation modeling relies on factor analytic methods to define the theoretical or latent variables. For a more thorough discussion of these procedures, see Maruyama and McGarvey (1980).

In instances when only one measure of each variable is available, it is assumed that the observed measure is not only valid but perfectly reliable as well. The structural model developed in this study relied on multiple measures of reading comprehension and mathematical achievement and single measures of test anxiety and prior achievement.

Insert Figure 1 Here

Of the four variables in the model, both prior achievement and worry are considered exogenous variables, or variables whose causes are largely unknown. Since it is not clear if either of these variables causally influences the other, the model allows them to covary. In path diagrams, such a relationship is typically depicted by a double-headed arrow. The interaction between prior achievement and worry is represented as the product of the observed scores on these variables. This interaction is also considered to be exogeneous, and may freely covary with prior achievement and worry in the model, but is not pictured in Figure 1. Reading comprehension and mathematical achievement are considered to be dependent upon prior achievement, worry, and/or their interaction. Hence, they are endogenous. Furthermore, the endogenous variable reading comprehension is viewed as caused directly by the exogenous variables, while the other endogenous variable, mathematical achievement, is viewed as caused by the exogenous variables and reading ability.

Method

Participants

The participants in this study were a group of 220 students entering a major urban university (N males = 103 and N females =117). The average age of the sample was 21 years old.

Instruments

Three types of measures were used in this study: (1) a self-report measure of test anxiety; (2) an archival index of prior academic achievement, high school grade point average; and (3) two standardized measures of achievement, a reading comprehension test and mathematics test. Each measure is described below.

Test Anxiety (Worry). This variable was measured using the Test Anxiety Inventory subscale of worry (Spielberger, C., Gonzalez, H.P., Taylor, C.J., Ross, G.R., and Anton, W.D., 1977) . The Test Anxiety Inventory is a self- report scale designed to measure individual differences in test anxiety as a situation-specific personality trait. The subscale measuring worry consists of eight items, and produces weighted scores ranging

from 8 to 32, with the higher score indicating a greater degree of worry. Test- retest reliability coefficients are reported in the range of .62 to .80. Moreover, the internal consistency reliability for this subscale is reported as .88 (Spielberger, et al. 1977).

Prior Academic Achievement. This variable was measured using the students' college admissions average, an index calculated on the basis of secondary school grades reported by the students' high school. This variable was assumed to be a relatively stable measure of prior academic achievement or academic skill level. In this sample, values ranged from 65 to 99.

Reading Comprehension. Reading comprehension was measured using the Reading Comprehension Test of the Descriptive Tests of Language Skills (College Board, 1978) . This is a forty item test in a multiple choice format. The test provides measures of three components of reading comprehension; recognizing main ideas, understanding direct statements and drawing inferences. The internal reliability coefficient or alpha coefficient (Cronbach, 1951) for the forty item scale was .89.

Mathematics Achievement. Mathematical achievement was assessed by use of a forty item test in a multiple choice format. This test measures two components of mathematical ability: general arithmetic ability and algebra. The arithmetic questions covered such topics as whole numbers, fractions, decimals and signed numbers, and word problems. The algebra items covered exponents, square roots, factoring and solving linear equations. The internal reliability coefficient or alpha coefficient (Cronbach, 1951) for the forty item scale was .94.

Procedures

The TAI and the standardized measures of mathematics achievement and reading comprehension were administered to groups of about thirty-five examinees under uniform testing conditions. The index of prior academic achievement, i.e., the college admission average, was obtained from each participant's college admissions files.

Results and Discussion

As noted earlier, one aim of this study was to examine the independent and interactive effects of prior achievement and test anxiety on performance on two competency exams. Moreover, since we are particularly interested in developing appropriate explanatory

models, the results of our analyses are presented separately for both males and females. Descriptive data, including means, standard deviations, and zero-order correlations are presented first. The model fitting procedures used to estimate the structural model are presented next. We conclude with a discussion of how well the derived model recreates the observed relationships and estimates the parameters of the two competing theoretical models.

Descriptive Data

Table 1, below, presents the means and standard deviations for both males and females. In addition to presenting the means and standard deviations for worry and prior achievement, comparable statistics are presented as well for the three reading subscales and the two mathematics subscales.

Insert Table 1 Here

In general the males in the sample had higher levels of prior achievement and lower levels of anxiety-related worry. Moreover, the males outperformed the females on all five subscales of the achievement measures. Table 2 presents the zero-order correlations among all observed measures for both males and females.

Insert Table 2 Here

For the most part, the correlations among prior achievement and the mathematics subscales are consistently strong for both males and females. The correlations among prior achievement and the reading comprehension subscales are in the expected direction, but are not as strong as the correlations with the mathematics subscales. The pattern of negative correlations among worry and the five achievement subscales suggests that when worry was high, performance on both competency tests was low for both males and females. Moreover, the negative correlations between prior achievement and worry suggest that those with lower levels of prior achievement exhibited higher levels of worry in the testing situation.

The observed zero-order correlations fit the expectations derived from both the deficit and the interference models. Since we can only guess which of these observed correlations are spurious and which are not, we applied structural modeling techniques to the data to explore hypothesized causes of poor test performance.

Fitting the Models

To determine whether the interference or the deficit hypothesis provides the better explanation of the performance data, the structural model in Figure 1 was fit separately for both the males and the females in the sample using the LISREL program. Covariance matrices, rather than correlation matrices, were used in the fit procedure so that valid comparisons of factor structure and regression coefficients between sexes would be possible. The model-fitting procedure began with the general "baseline" model (see Figure 1) in each group, and then tested a series of more restricted models created by placing various restrictions on the baseline model. These restrictions were of two types: equality or invariance restrictions which equate parameter values between sexes, and restrictions that force certain parameters to be zero in value. For example, the interference hypothesis would be contradicted, and the deficit hypothesis supported, if the structural regression parameters for the paths leading from worry to the reading and mathematics latent variables could be set to zero without compromising the fit of the model. Similarly, the deficit hypothesis would be contradicted if the regression parameters for the paths from prior achievement and the interaction term to the reading and mathematics latent variables could be set to zero while still maintaining a good fit.

Table 3 summarizes the series of model-fitting stages leading up to the final model. The goodness-of-fit for each model is indicated by the chi-square statistic produced by the LISREL program.

Insert Table 3 Here

Table 3 presents the chi-square statistic, the degrees of freedom, and the significance level associated with each of the eight models tested. A statistically significant chi-square value indicates a poor fit for the model. Specific model restrictions are tested by calculating the difference between the chi-square value for a model that relaxes the restrictions (assuming this model provides an adequate fit), and the chi-square statistic for a model that imposes the restrictions. Under standard assumptions, this "difference of chi-squares" will be distributed as chi-square in large samples, with degrees of freedom equal to the difference in the degrees of freedom for the two models. Several of these chi-square difference statistics are presented in Table 3, and are discussed below.

Model 1 in Table 3 is the model having the fewest restrictions, as pictured in Figure 1. No invariance restrictions are present in this model. The chi-square statistic indicates an adequate fit (X^2 =28.73, df=26, p=.324). Thus, Model 1 can serve as a baseline against which more restrictive models can be tested. Model 2 imposes

invariance restrictions on the factor loadings for the reading and math subtests. Although this model gives a fairly good fit overall, the chi-square difference statistic between models 1 and 2 indicates that the invariance restrictions may be too stringent (X^2 =7.04, df=3. $\overline{p}$<.10). Model 3 allows the factor loadings for the reading subtests to differ between sexes, while keeping the invariance restrictions on the math factor loadings. Model 3 provides an adequate fit, both overall and in comparison to Model 1. We can conclude, therefore, that while the factor loadings for the mathematics subtests appear to be the same between sexes, sex differences may exist in the factor structure of the reading subtests.

Model 4 imposed invariance restrictions on the structural regression parameters for the paths leading from prior achievement, worry, and their interaction to the reading and mathematics latent variables. This model fits adequately, and it appears that these parameters may be equated across sexes. Model 5 added an invariance restriction on the regression parameter for the path from the reading latent variable to the mathematics latent variable. This restriction, however, worsens the fit to some degree (X^2 =2.87, df=1, p<.10), suggesting that the effect of reading comprehension on mathematics achievement differs across groups. This restriction, therefore, was relaxed in all subsequent models. In Model 6, the structural parameters for the paths leading from the interaction variable to the reading and mathematics latent variables were restricted to zero for males and females. Model 6 fits adequately, indicating that the interaction between prior achievement and worry does not contribute substantially to predicting reading and mathematics achievement, once the separate effects of prior achievement and worry have been considered. In Model 7, the regression parameters for the paths leading from worry to the mathematics and reading latent variables were set to zero for both sexes. The chi-square difference statistic comparing models 6 and 7 indicates that these restrictions significantly worsen the fit (X^2 =10.55, df=2, p<.01). Model 8, in turn, allowed the regression parameter for the path from worry to the reading latent variable to be non-zero for both sexes, while the regression parameter for path from worry to mathematics was fixed at zero for both groups. This model improved upon Model 7 and suggests that worry has a significant negative effect on reading achievement even after the effects of prior achievement have been considered. Model 8, complete with the final estimates for the regression parameters and factor loadings, is pictured in Figure 2.

Insert Figure 2 Here

All the path coefficients presented in Model 8 are significantly different from zero ($p<.05$). Inspection of the path coefficients suggests that prior achievement has a modest direct effect on reading comprehension ($\gamma_1 = .111$) and a somewhat stronger direct effect on mathematics ($\gamma_2 = .379$). Test anxiety, on the other hand, had a modest negative effect on reading comprehension ($\gamma_3 = -.112$) and no discernable direct effect on mathematics achievement. Test anxiety, however, may have an indirect effect on mathematics performance by lowering reading comprehension which, in turn, affects mathematics achievement. With respect to sex differences, the paths from test anxiety and prior achievement are equal across groups. However, the path from reading comprehension to mathematics achievement is different for males and females. The factor loadings for reading comprehension are also somewhat different for males and females.

Conclusion

In the past, the deficit and interference models have been conceptualized by some (Kirkland and Hollandsworth, 1980) as being mutually exclusive. The causal model developed and tested in this paper suggests that both constructs, test anxiety and skill deficits, are necessary for understanding competence and test performance. Skill deficits affected performance on both the reading comprehension measure and the mathematics test. The effect of test anxiety, on the other hand, was detected on performance on the reading comprehension test. Surprisingly, the expected direct effect of test anxiety on mathematics performance was not found and appears to have been moderated by the effect of reading comprehension on mathematics performance. Moreover, the interaction between test anxiety and skill deficits was not found to be a significant explanatory variable.

Tobias (1985) has argued that a limited cognitive processing capacity formulation provides a useful way of accounting for the effects of both anxiety and skill deficits. According to Tobias (1985), "if it is assumed that people have a finite capacity for processing information..., then the cognitive representation of test anxiety must absorb some of students' processing capacity, leaving a reduced portion for task solution" (p.138). Obviously, such a limited capacity notion suggests that tasks demanding greater allocations of cognitive processing ability, as opposed to prior knowledge, are more susceptible to interference from test anxiety. The causal model derived in this study, which demonstrates the effects of test anxiety on reading

comprehension but not on mathematics performance, provides support for this limited capacity notion.

The model demonstrated that performance on the mathematics test was directly affected by skill or prior knowledge deficits and not test anxiety, while reading achievement was affected directly and equally by both explanatory variables. The role of prior knwowledge or skill on mathematics performance is apparent when one considers that the exam includes items in the domains of arithmetic and algebra. Those examinees who completed the mathematics sequence in secondary school prior to entering the university may have a preparation advantage that may serve to attenuate the effects of test anxiety on mathematics performance. In contrast, performance on the reading comprehension test depends to a large extent on the cognitive processes associatied with allocating attention and verbal reasoning and not on prior knowledge or skill. These component processes, Tobias (1985) argues, may be interfered with most by the worrying associated with test anxiety.

Further research in this area may benefit from an adaptation of the work being done by Embretson (1985) on componential latent trait models (CLTM) for testing the cognitive processes and cognitive demands required by certain tests. These CLTM models have demonstrated their utility for identifying individual differences in the cognitive variables underlying performance on specific test items. We believe a fruitful program of research may emerge from the application of both the structural modeling approach to test anxiety demonstrated in this paper and the latent trait models currently in use in modern test theory and test design. Work in this area would also be enhanced by studies which apply structural models of test anxiety and academic performance to various other groups of examinees, such as racial or ethnic minorities. This latter approach may prove useful for clarifying the role of cultural differences in test anxiety research.

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Table 1. Means and Standard Deviations by Sex

	Males (N=103)		Females (N=117)	
	Mean	SD	Mean	SD
Prior Ach.	77.17	7.93	75.48	7.41
Worry	13.87	4.59	14.49	4.67
Math 1	14.32	4.73	12.86	4.03
Math 2	12.41	6.29	9.55	5.51
Read 1	9.96	2.78	8.74	3.05
Read 2	7.58	2.69	6.79	2.55
Read 3	9.83	2.81	9.30	2.89

Table 2. Zero-order Correlations by Sex

	Prior Ach.	Worry	Math 1	Math 2	Read 1	Read 2	Read 3	
Prior Ach.		-.20	.56*	.58*	.21	.33*	.28*	**(Males)**
Worry	-.35*		-.23	-.24*	-.28*	-.25*	-.17	
Math1	.51*	-.32*		.86*	.39*	.48*	.33*	
Math 2	.64*	-.29*	.73*		.40*	.59*	.33*	
Read 1	.43*	-.25*	.39	.42*		.73*	.73*	
Read 2	.36*	-.27*	.43*	.38*	.68*		.74*	
Read 3	.38*	-.28*	.37*	.35*	.78*	.68*		

(Females) * $p<.05$

Table 3. Summaries of Goodness-of-Fit Indices for the Path Models

Model	Interpretation	X^2	df	p	diff. X^2	diff. df
1.	Baseline Model with no invariance restrictions	28.73	26	.324		
2.	Invariant factor loadings across groups	35.77	29	.180	7.04	3 *
3.	Factor loadings for Reading differ across groups	29.89	27	.319		
4.	Paths from Prior Ach and Worry invariant across groups	34.04	33	.418		
5.	Path from Reading to Math equal across groups	36.91	34	.336	2.87	1 *
6.	Paths for interaction of Worry and Prior Ach. equal to zero	34.74	35	.481		
7.	Paths for Worry equal to zero	45.29	37	.255	10.55	2 *
8.	Paths from Worry to Math equal to zero	36.42	36	.449		

* indicates a poor fitting model

Figure 1. Path diagram of predicted relationships among prior academic achievement, test anxiety (worry), reading comprehension and mathematics achievement. (Read 1 = main ideas; Read 2 = direct statements; Read 3 = inferences; Math 1 = arithmetic subscale; Math 2 = Algebra subscale.)

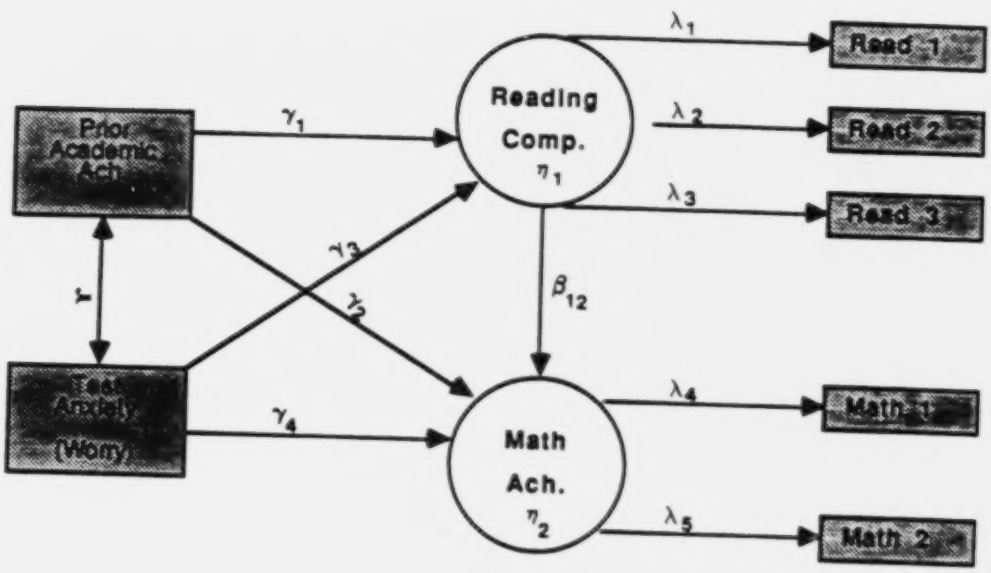

Figure 2. Path Model achieved with exclusion of the interaction between Prior Ach. and Anxiety.